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## NOVELTY OF PRODUCT INNOVATION: THE ROLE OF DIFFERENT NETWORKS

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### Abstract

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In the current competitive scenario, firms are driven to introduce products with a higher degree of novelty. Consequently, there is a growing need to understand the critical success factors behind radical innovation. Specifically, this work empirically and theoretically analyses the role of different types of collaborative networks in achieving product innovation and, more precisely, the degree of novelty. Using a longitudinal data of Spanish manufacturing firms, our results show that the continuity on the co-operative strategy, the type of partner and the diversity of collaborative networks are critical factors in achieving a higher degree of novelty in product innovation.

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**Keywords:** product innovation, degree of novelty, collaborative networks, technological partner.

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## **1. INTRODUCTION**

Current competitive pressures drive firms to introduce higher-quality products faster and at lower cost than competitors, a challenge that is becoming increasingly important in the rapidly-changing world (Barnett and Clark, 1998). Therefore, there is a growing interest in radical innovations considering their valuable contribution to the improvement of competitive advantages and the opportunities they offer to open up new markets (Lynn et al., 1996; McDermott and Handfield, 2000; McDermott and O'Connor, 2002). Consistent with this situation, entrepreneurs, researchers and politicians have taken a special interest in the different mechanisms and strategies for radical innovation achievement (Green et al., 1995; Danneels and Kleinschmidt, 2001).

Within this context, we explore organisational solutions that may contribute to increasing the degree of novelty of product innovation. Nevertheless, the measurement of radical innovations presents some considerable difficulties, perhaps due to the lack of agreement on a conceptual model explaining the dynamics of radical innovations (Garcia and Calantone, 2002). In fact, even though several studies highlight a distinction between radical and incremental innovation (Anderson and Tushman, 1990; Christensen and Rosenbloom, 1995; Tripsas, 1997), only a few of them clearly define the difference between both categories, and even fewer attempt to measure the degree of novelty (Dahlin and Behrens, 2005).

This lack of theoretical and empirical studies on this topic has driven us to throw some light on the dynamics of radical innovations. Specifically, we are interested in analysing the role of different types of collaborative networks in the achievement of product innovations and, more precisely, in their degree of novelty. Thus, an important question arises: Why are we interested in technological co-operations? Specifically, why could their impact on radical innovation be relevant?

Networking reflects a recognition that technological innovations are less and less the outcome of isolated efforts of the individual firm (Fischer and Varga, 2002). In many sectors, a firm's competitiveness may then depend not merely on the capabilities that can be created and exploited internally, but on the effectiveness with which it can gain access to sources of technological knowledge and capabilities beyond its own boundaries (Kogut, 1988). In the same line, Dziura (2001) points out that the growing number of participants in the innovation process - along with costs, demand, competition and technological capabilities- are influencing the rate and direction of innovation. Coherently, decisions about the sourcing of technological knowledge, the selection of partners and the management of relationships with those partners take on an enormous importance (Howells et al., 2004).

According to Ding and Peters (2000), the development of new businesses and product lines based on discontinuous innovations requires distinct inter-firm knowledge management practices. In this sense, knowledge management studies suggest that inter-firm collaborative networks enhance corporate innovative capability by facilitating flow of knowledge across companies. The idea is that networks can compensate for the resources and learning opportunities that the corporate hierarchy fails to provide in radical innovations. In this line, Stringer (2000) points out that external technological partners could play a crucial role as sources of radical innovation.

Although R&D alliances have not usually been used to explain innovation performance (Amara and Landry, 2005), there is a growing number of studies attempting to assess the effect of these networks on the firm's technological activity (Miotti and Sachwald, 2003; Belderbos et al., 2004a; Hoang and Rothaermel, 2005). However, understanding the performance of alliances is still an important, yet underresearched, topic in management innovation literature. Thus, in this paper we seek to make a theoretical as well as an empirical

contribution to the understanding of how firms that engage in collaborative R&D networks are more likely to develop product innovations with a higher degree of novelty. In particular, we are interested in answering the following questions:

1. How does technological co-operation affect the degree of novelty of product innovation?
2. Can we distinguish different effects depending on the type of network? That is, can we observe different trends according to type and diversity of partners? How does experience and continuity in the collaboration affect the degree of novelty?

To carry out our empirical study we use longitudinal data from the Spanish Business Strategies Survey for the years 1998 to 2002, widening the traditional focus on cross-sectional data of previous studies. This type of data allows us to introduce dynamic aspects into the analysis such as change of partner or continuity in the strategy of co-operation.

The rest of the article is structured as follows. Firstly, we develop some theoretical arguments to assess the effect of different types of networks on product innovation, particularly, on their degree of novelty. Secondly, we describe our data and the empirical models used. Next, we present and discuss the results obtained and, finally, we draw some relevant conclusions and managerial implications.

## **2. THEORETICAL FRAMEWORK**

### **2.1. Co-operation and performance of innovation activities**

Innovations are not only determined by factors internal to firms, but also by interactive processes involving relationships between firms with different actors of their environment

(Kline and Rosenberg, 1986). Several factors such as technological and market complexity and variability, could certainly increase the need for external resources (Nooteboom, 1999). However, market transactions are difficult to organise and can lead to major relational problems (Pisano, 1990), thereby hampering the acquisition of technological capabilities through external organisations (Mowery et al., 1998). In such context, co-operative agreements could iron out these problems and maximise firm value by effectively combining the partner's resources and exploiting complementarities (Das and Teng, 2000; Hagedoorn et al., 2000, Belderbos et al., 2004b).

Focusing on the objective of culminating the innovation process, what could we say about the impact of technological co-operations on the achievement of product innovation?

As evidenced by their ubiquitous use in many different industries (Hagedoorn, 1993), alliances have become an important strategic tool (Hoang and Rothaermel, 2005). Technological co-operation is considered to be a strategic mechanism to achieve a number of objectives: 1) to complete the innovation process; 2) to increase the technological capabilities of the firm; 3) to have access to public funding and 4) to gain access to new markets and to exploit new business opportunities (Cassiman, 1999, Hagedoorn et al., 2000, Bayona et al., 2001, Caloghirou et al., 2003, among others). Therefore, technological co-operation is expected to have a positive effect on innovation achievement. Could we say anything about the degree of novelty of the innovations achieved?

Radically innovative organisations are dominated by highly trained researchers who integrate a variety of different knowledge and skills to develop highly novel products for a range of customers (Whitley, 2002). Using data of UK innovating firms, Tether (2002) found that co-operation arrangements for innovation were more frequent amongst firms pursuing radical

innovations rather than incremental innovations. Similarly, Amara and Landry (2005) expect that firms introducing innovations with a higher degree of novelty are more likely to use a larger variety of sources of information to develop or improve their products.

Following the foregoing arguments, we formulate the following hypothesis related to the effect of technological collaboration on the achievement of product innovation:

*Hypothesis 1a: Technological co-operation encourages product innovation, particularly its degree of novelty.*

Starting from this premise, we consider it relevant to explore the effect that continuity in the technological co-operation could have on the degree of novelty of product innovation. Along these lines, the organisational learning literature (Levitt and March, 1988) shows evidence that those firms repeatedly engaged in a certain activity learn from experience, accumulate knowledge and apply it in future similar experiences. This argument is also valid in the context of alliances, since firms learn how to manage alliances by repeatedly engaging in these hybrid organisational forms. This general alliance experience has a positive effect on subsequent alliance performance because, among other reasons, firms develop and establish routines, policies and procedures based on previous experiences (Hoang and Rothaermel, 2005).

We argue that firms with previous co-operation experience, acquired through long-standing collaborative relationships, are more likely to improve the results of such collaborative agreements, which, in turn, could have positive implications for innovation outputs. Likewise, Amara and Landry (2005) establish that the more sustained and intense the interactions between firms and external sources of technical information are, the more likely the technical information will be used to develop innovations with a higher degree of novelty. According

to the previous arguments, and understanding “continuity” as the decision to maintain the strategy of co-operation over time, either with the same partner or with different partners, we establish the following hypothesis:

*Hypothesis 1b: Continuity in technological co-operation encourages product innovation, particularly its degree of novelty.*

## **2.2. Effects according to the type of partner**

The choice of a suitable technological partner becomes a crucial decision to be taken by the firm since there are significant differences among the types of partners that can determine how the collaboration is managed and what kind of innovation can be achieved (Whitley, 2002). We can find a variety of papers analysing the specific motivations behind co-operation with different partners (Fritsch and Lukas, 2001; Miotti and Sachwald, 2003; Tether, 2002; Belberbos et al., 2004b). There are, however, fewer works attempting to assess the effect of these partners on the firm’s technological activity (Miotti and Sachwald, 2003; Belderbos et al., 2004a). At this point, it would be interesting to present an intriguing question related to which partner will have a more significant effect on the degree of novelty of innovations.

The specific characteristics and objectives of each type of partner could lead us to anticipate that co-operation with different types of partners is likely to have different results. According to Whitley (2002), the development of innovative competences in co-operation with business partners (suppliers and customers, among others), allows the firm to gain considerable knowledge about new technologies, markets and process improvements. The empirical evidence found by Fritsch and Lukas (2001) and Miotti and Sachwald (2003) supports that

line of reasoning. Specifically, Miotti and Sachwald (2003) found that, in the case of French industry, vertical co-operation has a more significant impact on both product innovation (higher levels of market knowledge and, consequently, customer needs) and process innovation (closer to industrial reality). Also, on examining the distinct effect of suppliers and clients on the German manufacturing industry, Fritsch and Lukas (2001) found that innovative efforts directed at process improvements are more likely to involve co-operation with suppliers, whereas product innovations are associated with customer co-operation.

Co-operation with clients could be beneficial when the aim is to develop more novel or complex innovations (Tether, 2002). On these grounds, Amara and Landry (2005) point out that the advantages provided by customers and users as sources of information suggest that they could be used more frequently by firms when the innovations under development carry a higher degree of novelty.

Like customers, suppliers are also valuable sources of information sharing many of the advantages generated by customers to develop or improve products or processes. Indeed, the role of suppliers in the innovative process of firms is gradually growing, a fact that can be partly explained by the tendency of the 1990s of large firms to downsize and to focus more strongly on their core competencies (Amara and Landry, 2005).

In general terms, the purpose of co-operation with competitors is to carry out basic research and establish standards (Gemünden et al., 1992; Tether, 2002; Bayona et al., 2003). Thus, firms are likely to cooperate with competitors whenever they share common problems that are external to the competitor's sphere; for instance, a regulatory change (Tether, 2002). Precompetitive research programmes can also provide the grounds for co-operation with competitors (Lewis, 1990; Tidd and Trewhella, 1997; Dussauge and Garrette, 1998).



However, and following the arguments of Bayona et al. (2003), this type of co-operation does not seem to be the most appropriate mechanism to culminate the innovation process of new products, and even less so in the case of products with a high degree of novelty.

Historically, Research Organisations<sup>1</sup> (ROs) have not been focused on culminating the innovation process of firms, but on providing firms with new scientific and technological knowledge (Lundvall, 1992). However, this tendency has changed in the last few years and ROs have been under considerable pressure to move closer to industry for two main reasons. Firstly, governments have sought to encourage these institutions to undertake more industrially relevant research in order to assist the competitiveness of industry (Tether, 2002). Secondly, pressure on funding has pushed the academic environment into greater collaboration with industry (Gibbons et al., 1994). Coherent with this change of tendency, Belderbos et al. (2004b) highlight co-operation with ROs as the most effective way to achieve innovations intended to open new markets and segments. This would suggest that co-operation with ROs could involve more radical, or disruptive, innovations than those achieved with another type of partner.

Following the foregoing arguments, it seems reasonable to postulate that the impact on the degree of novelty of innovations will vary according to the type of partner, although it is difficult to establish which of them will have a more significant effect on novelty. Nevertheless, co-operation with competitors could be expected to have the weakest effect on product innovations. Therefore, we propose the following hypothesis:

*Hypothesis 2: The impact of technological co-operation on the degree of novelty of product innovation will vary according to the type of partner.*

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<sup>1</sup> Universities and Technological Centres.

### **2.3. Diversity and stability of networks**

A closer look at network composition - that is, the homogeneity or heterogeneity of the type of partners integrating it- would allow us to see whether the innovation outcomes, along with their degree of novelty, are conditional on the type of network involved. In this sense, a homogeneous network is defined as the one where all partners in co-operation have the same profile - i.e., clients - whereas a heterogeneous network is defined as the one where partners have different profiles - i.e., co-operation with clients and ROs simultaneously.

Previous works, such as Becker and Dietz (2004), found that the networking effects of interfirm R&D arrangements rise with the number of partners in co-operation. Furthermore, they explicitly state that the mix of heterogeneous parties engaged in R&D co-operation is one of the factors that raises the likelihood of achieving product innovation. In the light of these findings, we can argue that even when co-operation is a key factor in generating innovation, we should also highlight the importance of the number and variety of partners in co-operation.

Following this line of reasoning, Hoang and Rothaermel (2005) argue that the benefits of collaborating with the same partner over time should not be overstated. In fact, Gulati (1995) points out that additional alliances with the same partner may provide only redundant information and could actually result in inertia. On the contrary, it is to be expected that co-operating with many and varied partners will substantially enhance innovation activities due to the amount and variety of knowledge to be shared, which enables the alliance parties to complete their initial endowment of resources and capabilities. Summing up, we could say that the benefits of co-operating with the same partner over time should not be overestimated and, on the other hand, a broader spectrum of experiences with diverse partners could be advisable (Anand and Khanna, 2000).

Therefore, we expect that allying across a portfolio of partners can lead to better innovation outcomes. These arguments are the basis for the following hypothesis, relating the impact of a heterogeneous - versus a homogeneous- network of partners:

*Hypothesis 3a: Co-operation with diverse partners (heterogeneity) will have a more significant impact on the degree of novelty of product innovations than co-operation with only one type of partner (homogeneity).*

Assuming the more significant impact of heterogeneous networks and adopting a dynamic perspective, it seems reasonable to argue that those firms shifting from homogeneous networks to heterogeneous networks in terms of co-operation will improve their innovation outcomes. This change in the type of partners will modify the network stability. There is a growing recognition among scholars that instability is one of the main aspects to consider in order to explain the results obtained from partnering (Ariño and de la Torre, 1998). Moreover, from a theoretical point of view, recent developments in the alliance literature have suggested that instability may be a natural, or even desirable, aspect of collaboration rather than indicative of failure as most empirical studies assume (Reuer and Zollo, 2005).

In the light of the foregoing arguments, we propose the following hypothesis:

*Hypothesis 3b: Increasing the variety of partner - thus gaining access to diverse information and knowledge- raises the likelihood of achieving product innovations with a higher degree of novelty.*

### **3. METHODOLOGY**

#### **3.1. Sample and Data**

The source of our empirical analysis is the Spanish Business Strategies Survey (SBSS). It is a firm-level panel of data compiled by the Spanish Ministry of Science and Technology and the Public Enterprise Foundation (*Fundación Empresa Pública*, FUNEP) during the 1991- 2002 period. The SBSS covers a wide sample of Spanish manufacturing firms operating in all industry sectors; approximately 1,800 observations are available for each year. The sample is representative of the population of Spanish manufacturing firms with 10 to 200 employees. In this range, the sample is random and stratified according to firm size (in terms of the number of employees) and industry sector (Fariñas and Jaumandreu, 2000). The 1998 survey was the first one to include information about firms engaged in technological co-operation, with partner specifications (i.e., type(s) of partner(s) in co-operative arrangements). Consequently, our study includes data corresponding to the 1998-2002 period.

Our final sample comprised a total of 1,300 firms that have remained in the survey along the five-year period, which makes up a complete panel of 6,500 observations. The longitudinal nature of the sample allows us to control for potential unobserved firm effects that may be correlated with the impact of technological co-operation (Belderbos et al., 2004a). It should be noted that, like Fritsch and Lukas (2001) or Miotti and Sachwald (2003), we have included in this work all the firms responding to the survey, with no distinction between innovating and non-innovating firms since it could give rise to biased results acknowledged by earlier studies focused on the behaviour of innovative firms (Bayona et al., 2001, 2003; Tether, 2002; Cassiman and Veugelers, 2002).

## **3.2. Measures and variables**

### *3.2.1. Dependent variables*

Patent data and, more precisely, information about patent citations provide valuable insight into the dynamics of radical innovations (Reitzig, 2003; Dahlin & Behrens, 2005). Although we do not have specific information about the content of patents, we do know the number of patents generated. However, we would still be unable to faithfully capture the degree of radicality of innovations given the ample evidence that only a low percentage of patents actually turn into radical innovations (Tushman and Anderson, 1986; Tripsas, 1997; Henderson, 1993). On the other hand, Acs et al. (2002) remind us that although patents are good indicators of new technology creation, they do not measure the economic value of these technologies (Hall et al., 2001) and, consequently, their degree of radicality remains unmeasured.

So, how can we capture the degree of novelty of product innovations? Our database allows us to make a distinction between innovations denoting an incremental change (changes in the design, presentation or any of the components) and innovations denoting a more relevant change (resulting in a product incorporating new functions). With this information, we can classify innovations according to their degree of novelty.

The dichotomous variable (RADICAL) captures innovations with a higher degree of novelty and takes the value 1 if the firm declares new product functions resulting from innovation, and value 0 otherwise. Next, the dichotomous variable (INCREM) captures incremental product innovations and takes the value 1 for innovations with a lower degree of novelty.

### 3.2.2. *Explanatory variables*

According to our theoretical arguments, we need to construct variables to assess the impact of the different types of networks on product innovations and their degree of novelty.

Firms indicate whether or not they have engaged in technological co-operation, which allows us to construct a dummy variable (COOP) to capture the effect of technological co-operation on product innovation. To analyse the impact of continuity in co-operative agreements we have taken the last year of the survey (2002) as reference in order to observe the co-operative trend of the firm in the previous years. Then we constructed three dummy variables indicating the continuity - or discontinuity- in the co-operative strategy of the firm. Specifically, these variables indicate: i) whether the firm engaged in co-operative arrangements over a one-year period only (COOPMIN); ii) whether the firm engaged in co-operative arrangements over a two or three-year period (COOPMED); iii) whether the firm engaged in co-operative arrangements over a four or five-year period (COOPMAX).

We distinguish four dichotomous variables in order to explain the effects of the different types of collaborative partner: i) co-operation with ROs (COOPRO), ii) co-operation with customers (COOPCUST), iii) co-operation with suppliers (COOPSUP), and iv) co-operation with competitors (COOPCOM). Initially, these variables are not exclusive since firms may have co-operated with diverse partners simultaneously. However, to avoid potential multicollinearity problems, we will also consider these variables exclusive<sup>2</sup> for some of the estimates.

According to the four categories mentioned, we have constructed two dichotomous variables to capture partner diversity in the network: i) a homogeneous collaborative network is defined

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<sup>2</sup> So that a firm declaring co-operation with a particular type of partner will not have co-operated with any other. On the other hand, to control for firms declaring co-operation with more than one type of partner we have included an additional variable defined as MULTPART.

if the firm has co-operated with only one type of partner (ONEPART), ii) a heterogeneous collaborative network is defined if the firm has co-operated with partners belonging to, at least, two different categories (MULTPART), although the number of partners in each category remains unknown.

Finally, we attempt to capture co-operative stability by generating three dichotomous variables<sup>3</sup>: i) the firm expanded its pool of partners by shifting from co-operation with only one type of partner to co-operation with diverse partners at some point in the period (CHANPART), ii) the firm has co-operated with only one type of partner over the five-year period (FIXONE), and iii) the firm has co-operated with diverse partners over the five-year period (FIXMUL).

### *3.2.3. Control variables*

We have included controls for firm-specific characteristics - size, R&D intensity and export intensity- and for sectoral characteristics. Additionally, when using the five year period of the sample, year dummy variables have also been included.

Size is measured by sales (SALES) and square of sales (SALES2) to capture potential non-linear effects (Cassiman and Veugelers, 2002). Following Becker and Dietz (2004), to reasonably explain the production of innovations we must include the intensity of R&D - ratio of total R&D expenditure to total sales (R&D). In addition, a control variable for the firm's export activity - ratio of total exports to total sales (EXPORT) has also been introduced.

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<sup>3</sup> The year 2002 is taken as reference for this analysis.

Finally, to control for the sectoral differences we have used the classification proposed by Pavitt (1984), since it allows us to capture sectoral nuances other than the purely technological. According to this classification, four dummies are included: i) supplier-dominated sectors (SUPP-DOM), ii) scale-intensive sectors (SCALE), iii) specialised suppliers sectors (SPEC-SUPP), iv) science-based sectors (SCIENCE).

Table 1 contains the descriptive statistics and correlations of the variables used in the study<sup>4</sup>.

(Table 1 about here)

### 3.3. Model specification

Both dependent variables - RADICAL and INCREM- are dichotomous in nature; accordingly, estimation models such as *logit* or *probit* (Aldrich and Nelson, 1984; Greene, 2000) would normally be appropriate. However, as the error terms of the two models are likely to be correlated, an extension of probit known as *bivariate probit* (Greene, 2000) is usually a more appropriate estimator. The bivariate probit model has the following specification (Breen, 1996):

$$Z_{i1} = \mathbf{b}_1' \mathbf{x}_{i1} + \mathbf{e}_{i1}; \quad y_{i1} = 1 \text{ si } z_{i1} > 0, \quad y_{i1} = 0 \text{ si } z_{i1} \leq 0 \quad [1.1]$$

$$Z_{i2} = \mathbf{b}_2' \mathbf{x}_{i2} + \mathbf{e}_{i2}; \quad y_{i2} = 1 \text{ si } z_{i2} > 0, \quad y_{i2} = 0 \text{ si } z_{i2} \leq 0 \quad [1.2]$$

$$(\mathbf{e}_{i1}, \mathbf{e}_{i2}) \sim N(0,0,1,1, \mathbf{r}) \quad [1.3]$$

The bivariate probit model produces estimates of the coefficient vectors  $\mathbf{b}_1$  and  $\mathbf{b}_2$  for the two equations;  $\mathbf{r}$ , the correlation between the error terms ( $\mathbf{e}_{ij}$ ) of the equations; and standard errors for these parameters. We can then test whether or not the correlation between the equations is

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<sup>4</sup> It should be noted that this table does not show descriptive statistics and correlations of those variables resulting from a combination of other variables. Particularly, those capturing the co-operative evolution of the firm along the period, only available for the year 2002.



statistically significant, to decide whether the bivariate estimator was necessary<sup>5</sup>. The bivariate probit model was estimated using the Stata 8 routine, based on the method of simulated maximum likelihood.

The difference in the specification of each model lies in the type of network (i.e., explanatory variables used to contrast each of the hypotheses formulated). Another nuance is the time period under study, since the entire five-year period will be used to contrast some of the hypotheses (H1a, H2, H3a), whereas other hypotheses (H1b, H3b) will be contrasted using the last year of the sample period. However, there will be no difference in either the specification of dependent variables or in the controls.

## 4. EMPIRICAL RESULTS

### 4.1. Co-operation and continuity

Table 2 provides estimates of the impact of co-operation - and its continuity- on the degree of novelty of product innovation. The  $\rho$  parameter is highly significant in both models, indicating that the error structures of the equations are correlated, suggesting that the bivariate model is the correct specification. Moreover, as indicated by the Wald test, both models show high joint significance of the variables.

(Table 2 about here)

Model 1 is used to test H1a with data corresponding to the five-year period (1998-2002). As expected, co-operation has a positive and significant impact on the likelihood of achieving product innovations, both incremental ( $\beta = 0.651$ ,  $p < 0.01$ ) and radical ( $\beta = 0.849$ ,  $p < 0.01$ ). Moreover, if we compare both coefficients, we observe that the impact of co-operation

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<sup>5</sup> If the correlation is not significant, separate (univariate) probit estimation of the equations is preferable as bivariate probit is less efficient than estimating separate models when the error terms are not correlated (Greene, 2000:853-4).

on the degree of novelty is positive, since its effect on the likelihood of achieving radical innovations is more significant than that of achieving incremental innovations.

Regarding business controls, it is worth mentioning that the impact of R&D efforts and size on the likelihood of achieving innovations is only significant in the case of radical innovations. On the other hand, export intensity only has a positive and significant effect on the likelihood of achieving incremental innovations. As regards sectoral controls, it should be noted that they have a significant impact according to the degree of novelty of product innovations. Thus, the fact of not belonging to the omitted sector (SUPP-DOM) increases the likelihood of achieving innovations with a higher degree of novelty, whereas in the case of incremental innovations the effect is the contrary.

As expected, the results of Model 1 provide empirical evidence supporting H1a, that is, the impact of co-operation on product innovations is positive and significant, particularly on innovations with a higher degree of novelty.

We estimate Model 2 to test the impact of continuity in the strategy of co-operation on product innovation, presented in H1b. To identify the co-operative evolution of the firm, we conducted our analysis using the observations for the year 2002, as well as taking into account the co-operative trend of the firm over the period 1998-2002. Continuity in the strategy of co-operation shows a positive and growing impact on the likelihood of achieving both types of innovations. Thus, the effect on incremental innovations appears to be more significant for firms with greater continuity in their co-operation strategy: COOPMAX, ( $\beta = 0.768, p < 0.01$ ), COOPMED ( $\beta = 0.654, p < 0.01$ ) and COOPMIN ( $\beta = 0.336, p < 0.1$ ). We also observed that the impact on radical innovations is still more significant for firms with greater continuity in their co-operation strategy: COOPMAX ( $\beta = 1.185, p < 0.01$ ),

COOPMED ( $\beta = 0.757, p < 0.01$ ) and COOPMIN ( $\beta = 0.543, p < 0.1$ ). The fact that the coefficients are higher in the case of radical innovations leads us to conclude that continuity in the strategy of co-operation increases the degree of novelty of product innovation, thus supporting H1b. Finally, we observe that business and sectoral controls have a similar impact than Model 1, although the coefficients are slightly less significant.

#### 4.2. Effects according to the type of partner

Table 3 presents the estimated results for the impact of each particular type of partner on the degree of novelty of product innovation. As before, the  $\mathbf{r}$  parameter is highly significant in both models and, therefore, the bivariate model is the correct specification. In this case, the Wald test of both models is also indicative of a high joint significance of the variables. By looking at the figures in Table 3, we can observe that co-operation exerts a distinct effect according to the type of partner.

(Table 3 about here)

Model 3 shows that suppliers are the type of partner with the most significant effect on both incremental ( $\beta = 0.607, p < 0.01$ ) and radical ( $\beta = 0.492, p < 0.01$ ) innovations; although in the latter case the difference versus clients and ROs appears to be smaller. Contrary to our expectations, ROs do not have the most significant impact on the degree of novelty although they do have a positive and significant effect. On the other hand, competitors behave as expected: we observe that when firms co-operate with this type of partner, the likelihood of achieving radical innovations is lower than the average.

It should be noted that the variables for the type of partner in Model 3 are not exclusive, that is, a firm co-operating with clients could also be co-operating with suppliers, ROs and/or

competitors simultaneously. This could entail potential multicollinearity problems<sup>6</sup> to be solved in Model 4. Although not included in the table, we have estimated four specifications considering only each type of partner as explanatory variable, so as to isolate the marginal effect of each partner and iron out the multicollinearity problem. We obtained similar results.

Model 4 includes a number of variables to capture only exclusive co-operations with a particular type of partner. For example, the variable COOPRO takes the value 1 if the firm co-operates exclusively with ROs. Additionally, we include the variable MULTPART to capture the different cases where firms have co-operated with more than one type of partner. With this definition of variables, the analysis does not capture co-operation with competitors since firms co-operating exclusively with this type of partners are very few.

Compared to Model 3, Model 4 offers a number of nuances. Firstly, all types of partners have a positive and significant effect on the likelihood of achieving incremental and radical innovations. We also observe that exclusive co-operation with suppliers still has the most significant impact on incremental innovations ( $\beta = 0.903, p < 0.01$ ) unlike radical innovations, where co-operation with clients ( $\beta = 0.856, p < 0.01$ ) and, particularly, with diverse partners ( $\beta = 1.017, p < 0.01$ ) has the most significant impact. Like Model 3, co-operation with ROs does not have the most significant impact on the degree of novelty of innovations ( $\beta = 0.476, p < 0.01$ ). In both models, business and sectoral effects are consistent with the results obtained in previous models (particularly Model 1).

The empirical evidence obtained allows us to observe differences in the impact of technological co-operation according to the type of partner, thus offering empirical support for H2. The results obtained after considering exclusive co-operations with a particular type

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<sup>6</sup> This could explain the negative effect of clients on incremental innovations.

of partner show that co-operation with clients has the most significant impact on achieving innovations with a higher degree of novelty. The impact of co-operation with ROs on the degree of novelty, although positive, is not as significant as co-operation with suppliers and clients. In any case, co-operation with diverse partners has the most significant impact on the degree of novelty of innovations. This result has also been supported by the results obtained in Model 5.

### 4.3. Diversity and stability

Figures in Table 4 show the results of the bivariate probit analyses related to diversity and stability of the network (H3a and H3b). Again, the bivariate probit model proves to be the correct specification since the  $\mathbf{r}$  parameter is highly significant in both models. Likewise, the Wald test indicates that the variables are robust.

(Table 4 about here)

Model 5 attempts to capture the distinct effect of co-operation with a particular type of partner (ONEPART) as opposed to co-operation with diverse partners (MULTPART). We explore the effect of partner diversity by comparing what we have called 'homogeneous network' to a 'heterogeneous network'. Our findings show that co-operation with diverse partners ( $\mathbf{b} = 1.013, p < 0.01$ ) has a more significant impact on radical innovation than co-operation with a particular type of partner ( $\mathbf{b} = 0.629, p < 0.01$ ). On the other hand, there are only slight differences in the impact of both networks on incremental innovations (this result is coherent with Model 4).

As anticipated in Model 4 (the effect of the different types of partner), the results obtained in Model 5 support H3a. In fact, partner diversity creates a heterogeneous network which enables the firm to have access to diverse sources of knowledge and thus increase the degree

of novelty of product innovation, as Becker and Dietz (2004) found on studying the likelihood of realizing product innovations.

Once again, for our stability analysis (Model 6), we take the last year in the sample period as reference so as to identify any change in the co-operative trend of the firm. In this case, we clearly observe how the strategy of co-operation with one particular type of partner, FIXONE, has a less significant effect on product innovations. On the other hand, the likelihood of achieving incremental innovations is higher for firms co-operating with diverse partners ( $\beta = 0.644, p < 0.01$ ). Likewise, the likelihood of achieving radical innovations is also higher for firms co-operating with diverse partners or increasing the number of partners over the period under study – FIXMULT ( $\beta = 0.738, p < 0.01$ ) and CHANPART ( $\beta = 0.791, p < 0.01$ ).

Model 6 allows us to study the evolution and trend –stability or instability– of the co-operative strategy of each firm over the sample period. In this sense, our main finding is that the likelihood of increasing the degree of novelty of innovations is higher for firms shifting from homogeneous networks to heterogeneous networks, as stated in H3b. These results also support H3a, since firms co-operating with a heterogeneous network improve their performance in terms of radical and incremental innovation.

## 5. DISCUSSION AND CONCLUSIONS

The main contribution of this paper is to shed some light on some of the factors that can explain or facilitate product innovation achievements as well as increase the degree of novelty of those innovations. The inherent difficulty of measuring the novelty of innovations

(Dahlin and Behrens, 2005), could explain the fact that studies on radical innovation are still scarce.

Specifically, this work is a theoretical and empirical attempt to analyse the effect of different types of technological co-operation on product innovations and their degree of novelty. We have considered the impact of co-operation and its continuity, the type and diversity of partners and the stability or instability of these networks over the period under study.

For our empirical analysis we use a complete panel of Spanish manufacturing firms, with observations for the period 1998-2002. The longitudinal nature of the sample allows us to use adequate estimation techniques and capture the dynamic effects. The suitability of our database becomes evident when analysing the continuity in the strategy of co-operation as well as any change in the collaborative network. Our results provide interesting insights into the impact of different types of technological co-operation on the degree of novelty of product innovation.

Thus, firms engaged in technological alliances are more likely to achieve both radical and incremental product innovations. This result is coherent with previous studies (Miotti and Sachwald, 2003; Becker and Dietz, 2004; among others), where the degree of novelty was not differentiated.

Continuity in the the strategy of co-operation can also be a critical factor for innovation outcomes. As stated in the postulates of the organisational learning theory, firms repeatedly engaged in a particular activity learn from experience and apply accumulated knowledge to future experiences. Indeed, our results show the important role of accumulated co-operative experience to achieve product innovation with a higher degree of novelty.

Moreover, we found that different types of partner have different effects on product innovation and the degree of novelty. Specifically, our findings show that co-operation with clients has the most significant impact on innovations with a higher degree of novelty. This result is coherent with previous studies (Tether, 2002; Amara and Landry, 2005) arguing that clients can provide relevant information on market practices and the uses of the products. As regards vertical co-operations, it should be noted that suppliers also play an important role in the achievement of radical innovations, even more so in the case of incremental innovations. This result is also coherent with the observation that the role of suppliers in the innovative process of firms is growing (Amara and Landry, 2005). Contrary to the arguments put forward by Belderbos et al., (2004b), the impact of co-operation with ROs on the degree of novelty, although positive, is not as significant as co-operation with suppliers and clients. This result could be explained in the light of the characteristics and innovative culture of the Spanish industrial firms: even when Spanish firms consider ROs to be valuable sources of information to acquire basic knowledge, there is not enough trust in the potential of these institutions to achieve radical innovations (COTEC, 1999). Finally, it is worth mentioning that co-operation with competitors does not have a significant impact on the degree of novelty of product innovations.

We find our results to be particularly interesting regarding network heterogeneity and changes in the network composition. In fact, the most significant impact on the degree of novelty of innovations results from co-operation within a network comprised of different types of partners. This heterogeneity promotes access to diverse sources of information and enables the firm to transfer and apply that knowledge to achieve more radical innovations. Accordingly, any change in this direction –that is, increasing the number and type of partners in the network– substantially improves the degree of novelty of product innovations. This



result is coherent with the idea that network changes could be beneficial (Reuer and Zollo, 2005) and, in our case, we observe that the most favourable changes are correlated with greater heterogeneity in the network.

Our findings can provide useful managerial implications. In the current competitive scenario, the achievement of innovations with a certain degree of novelty is becoming increasingly important. In this paper we show evidence that different types of collaborative networks can be critical success factors to achieve innovation with a higher degree of novelty. The practical value of these findings lies in a better understanding of how the configuration of a collaborative network affects its own performance. Therefore, managers must be aware of the importance of partner suitability, network heterogeneity and continuity in the strategy of co-operation, since these are determinant factors for superior alliance performance in terms of innovation and further development of the firm's competitive advantage.

Finally, this paper is also a step forward in methodological terms, for it provides a measure for the degree of novelty of product innovations. In any case, we believe there is room for improvement in this respect and that it certainly poses an interesting challenge for future research.

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**Table 1. Means, Standard Deviations and Correlations**

	Mean	St.Dev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. INCREM	0.128	0.335	1															
2. RADICAL	0.124	0.330	-0.14	1														
3. COOP	0.335	0.472	0.20	0.31	1													
4. COOPRO	0.075	0.263	0.03	0.01	0.40	1												
5. COOPCUS	0.017	0.130	0.03	0.05	0.18	-0.03	1											
6. COOPSUP	0.039	0.194	0.11	0.05	0.28	-0.05	-0.02	1										
7. COOPCOM	0.000	0.017	0.04	-0.00	0.02	-0.00	-0.00	-0.00	1									
8. ONEPART	0.131	0.338	0.11	0.06	0.54	0.73	0.34	0.51	0.04	1								
9. MULTPART	0.203	0.402	0.14	0.31	0.71	-0.14	-0.06	-0.10	-0.00	-0.79	1							
10. R&D	0.007	0.023	0.09	0.18	0.34	0.04	0.04	0.05	-0.00	0.08	0.33	1						
11. SALES	0.093	0.417	0.03	0.08	0.18	0.02	0.00	0.01	0.00	0.03	0.19	0.06	1					
12. EXPORT	0.198	0.264	0.10	0.12	0.35	0.09	0.03	0.07	0.00	0.12	0.31	0.16	0.14	1				
13. SUPP-DOM	0.294	0.455	0.03	-0.11	-0.18	-0.07	-0.04	-0.00	0.00	-0.07	-0.15	-0.09	-0.09	-0.13	1			
14. SCALE	0.423	0.494	-0.04	-0.02	0.01	0.05	-0.04	0.00	0.00	0.02	-0.00	-0.05	0.10	0.03	-0.55	1		
15. SPEC-DOM	0.151	0.358	0.00	0.13	0.11	-0.02	0.04	0.02	-0.00	0.00	0.13	0.13	-0.02	0.09	-0.27	-0.36	1	
16. SCIENCE	0.130	0.336	0.02	0.05	0.09	0.05	0.07	-0.02	-0.00	0.05	0.07	0.07	0.00	0.03	-0.24	-0.33	-0.16	1

**Table 2. Bivariate Probit Analysis: Explanatory models to test the impact of co-operation and its continuity on the degree of novelty**

	Model 1		Model2	
	INCREM	RADICAL	INCREM	RADICAL
<b>Explanatory variables</b>				
COOP	0.651***	0.849***		
COOPMIN			0.336*	0.543***
COOPMED			0.654***	0.757***
COOPMAX			0.768***	1.185***
<b>Controls</b>				
R&D	0.630	1.928***	3.96*	0.853
SALES	-0.014	0.498***	-0.362	1.150*
SALES2	0.000	-0.712***	-0.010	-4.816
EXPORT	0.239***	0.026	0.336*	-0.016
SCALE	-0.314***	0.127**	-0.236**	0.088
SPEC-SUPP	-0.277***	0.499***	-0.279*	0.316**
SCIENCE	-0.195***	0.277***	-0.217	0.220
<b>Intercept</b>	-0.139***	-1.832***	-1.574***	-2.061***
<hr/>				
$LR \sim c^2 : r = 0$	181.797***		5.619**	
Wald test of full model: $\chi^2$	1244.94***		275.43***	
Log pseudo-likelihood	-4218.82		-756.07	
Number of observations (Period)	6500 (1998-2002)		1300 (2002)	
<hr/>				
Unstandardised regression coefficients are shown. Time controls are included in the model 1.				
* p < 0.10; ** p < 0.05; *** p < 0.01.				



**Table 3. Bivariate Probit Analysis: Explanatory models to test the effect of different types of partner on the degree of novelty**

	<b>Model 3</b>		<b>Model 4<sup>1</sup></b>	
	INCREM	RADICAL	INCREM	RADICAL
<b>Explanatory variables</b>				
COOPRO	0.131**	0.344***	0.468***	0.476***
COOPCUS	-0.128*	0.281***	0.653***	0.856***
COOPSUP	0.607***	0.492***	0.903***	0.778***
COOPCOM	-0.193	-0.194*		
MULTPART			0.641***	1.017***
<b>Controls</b>				
R&D	1.122**	1.844**	0.704	1.458**
SALES	0.000	0.451***	-0.010	0.426***
SALES2	-0.040	-0.682***	-0.005	-0.625***
EXPORT	0.315***	-0.046	0.250***	-0.033
SCALE	-0.273***	0.154***	-0.301***	0.146**
SPEC-SUPP	-0.254***	0.487***	-0.286***	0.470***
SCIENCE	-0.137**	0.332***	-0.185***	0.282***
<b>Intercept</b>	-1.353***	-2.061***	-0.140***	-1.825***
<hr/>				
<i>LR ~ c<sup>2</sup> : r = 0</i>	107.77***		172.20***	
Wald test of full model: $\chi^2$	1407.53***		1365.63***	
Log pseudo-likelihood	-4241.05		-4182.50	
Number of observations (Period)	6500 (1998-2002)		6500 (1998-2002)	

Unstandardised regression coefficients are shown. Time controls are included in both models.

<sup>1</sup> In Model 4, to control for multicollinearity problems, co-operation with a particular type of partner is an exclusive category

\* p < 0.10; \*\* p < 0.05; \*\*\* p < 0.01.

**Table 4. Bivariate Probit Analysis: Explanatory models to test the effect of diversity and stability on the degree of novelty**

	Model 5		Model 6	
	INCREM	RADICAL	INCREM	RADICAL
<b>Explanatory variables</b>				
ONEPART	0.651***	0.629***		
MULTPART	0.647***	1.013***		
CHANPART			0.483***	0.791***
FIXMULT			0.527***	0.738***
FIXONE			0.374**	0.248*
<b>Controls</b>				
R&D	0.729	1.461**	4.665**	2.277
SALES	-0.019	0.424***	0.051	1.870***
SALES2	0.008	-0.623***	-3.173	-9.40*
EXPORT	0.240***	-0.021	0.452***	0.193
SCALE	-0.310***	0.139**	-0.190	0.107
SPEC-SUPP	-0.279***	0.478***	-0.223	0.303**
SCIENCE	-0.200***	0.282***	-0.152	0.246
<b>Intercept</b>	-0.139***	-1.824***	-1.510***	-1.859***
$LR \sim c^2 : r = 0$	139.246***		87.491***	
Wald test of full model: $\chi^2$	1317.31***		257 ***	
Log pseudo-likelihood	-4198.149		-780.62	
Number of observations (Period)	6500 (1998-2002)		1300 (2002)	
Unstandardised regression coefficients are shown. Time controls are included in the model 5.				
* p < 0.10; ** p < 0.05; *** p < 0.01.				